Hematologic System
Unit 7: Chapter 29
AMSN 2021
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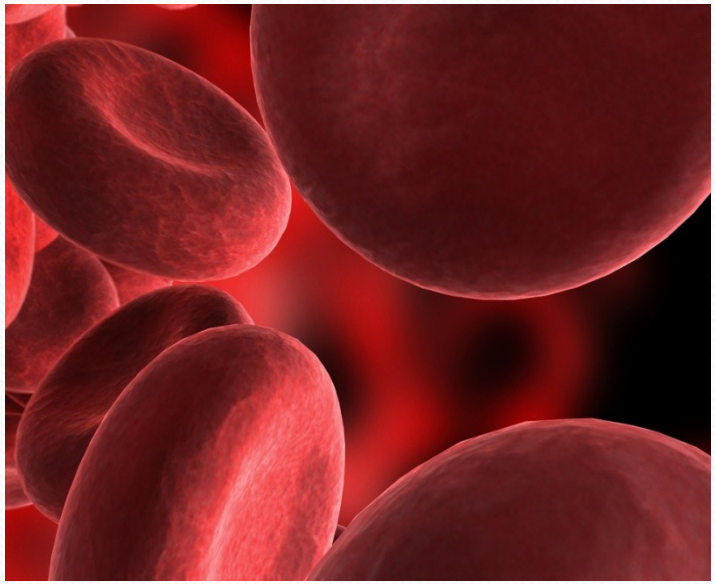


- Hematopoiesis: the process of formation and development of blood cells – occurs in the bone marrow

- Blood cells are formed in the flat and irregular shaped bones: ends of long bones, pelvic bones, vertebrae, sacrum, sternum, ribs, flat cranial bones, and scapulae

- Blood cells are continuously being formed at a rate of 10 billion cells/day

- Hematopoiesis – stem cells are poorly characterized, undifferentiated cells that exist within the red marrow.

- Growth factors (cytokines) stimulate bone marrow and cause differentiation of stem cells

- As stem cells mature and differentiate, they form Erythrocytes (RBC), Leukocytes (WBC), and Thrombocytes (Platelets)

BLOOD

- Blood : A type of connective tissue that performs 3 major functions
  - Transportation
  - Protection
  - Regulation
  - 2 Major components of blood
  - Plasma (55%)
  - Blood cells (45%)
    - RBC
    - WBC
    - Platelets

BLOOD

- Circulating blood performs the following:
  - Supplies cells with O2 and nutrients
  - Removes waste products
  - Transports hormones
  - Protects body from microorganisms
  - Promotes hemostasis (arrest of bleeding)
  - Regulates body temperature
  - Acid base balance
- About 8% of our total body weight is blood
- Female 4-5L of blood
- Male 5-6L of blood

PLASMA

- Plasma is the liquid portion of the blood (55% of the blood)
  - Straw colored
  - Composed of water, proteins, nutrients, metabolic wastes, respiratory gases, enzymes, hormones, clotting factors, and inorganic salts

Serum- plasma minus the clotting factors

Red Blood Cells: Erythrocytes

- Carry O2 to the cells and help transport CO2 back to the lungs for removal.
- Flexible in order to pass easily through the capillaries
- Assist with maintenance of acid/base balance
- Acts as a buffer
- Primarily composed of large molecule: Hemoglobin
- Packed in each RBC are 200-300 million molecules of Hemoglobin.

- Erythropoiesis: the process of RBC production
  - Stimulated by hypoxia and controlled by erythropoietin

- Erythrocytes are produced in the red bone marrow. Required for this process are:
  - Precursor cells / Erythropoietin
  - A proper microenvironment – hormone levels
  - Adequate supplies of protein, iron, vitamin B12 (Cobalamin), vitamin B2 (Riboflavin), folic acid, vitamin B6 (pyridoxine), pantothenic acid, niacin, ascorbic acid, and vitamin E

- Reticulocyte: Immature erythrocyte
  - Immature erythrocytes leave bone marrow and circulate as nucleated reticulocytes. They enter spleen and mature to then reenter circulation
    - Reticulocyte count: measures rate at which new RBC appear in circulation
    - Mature into RBC's within 48 hours of release into circulation

- Hemolysis: Destruction of erythrocytes
  - Hemolysis removes abnormal, defective, damaged, and old RBCs from circulation.

White Blood Cells: Leukocytes

- Originate from stem cells within bone marrow
- Appear white when separated from blood
- Types of WBC
  - Granulocyte: Contain granules within the cytoplasm
    - Neutrophils – 50-70%
    - Basophils – 0-2%
    - Eosinophils -2-4%
  - Agranulocyte: Do not have granules within the cytoplasm
    - Lymphocytes – 20-40%
    - Monocytes – 4-8%

Granulocytes

- Phagocytosis- Primary function of granulocytes
- Neutrophils-Primary cell in phagocytosis
- Eosinophils-allergic reactions
- Basophils-releases chemicals
- Lymphocytes-immune response. B + T
- Monocytes-phagocytic, 2nd to arrive
  - Macrophages – monocytes that migrate to tissue

Neutrophils

- Granulocytes
  - Neutrophils
    - Primary function is phagocytosis
    - Primary phagocytic cells involved in acute inflammatory response
    - Mature neutrophil is segmented (“seg”), with multiple segments in its nucleus
    - Immature neutrophils are called bands (for the nonsegmented appearance of the nucleus).
    - Mature neutrophils are more efficient phagocytes than bands.

Neutrophils

- Granulocytes
  - Neutrophils
    - First at site of infection
    - An increase in percent of bands is called a shift to the left, meaning the bone marrow is releasing less-mature cells into circulation in response to a site of injury (increased in acute infection and inflammation).
    - Life span: 2 to 14 days

Eosinophils

- Granulocytes
  - Eosinophils
    - Account for only 2% to 4% of all WBCs
    - Have a reduced ability for phagocytosis compared with neutrophils
    - Granules contain histamine.
    - Engulf antigen-antibody complexes formed during an allergic response
    - Defend against parasites
    - Found in large numbers in lungs and GI tract

Basophils

- Granulocytes
  - Basophils
    - Make up less than 2% of all leukocytes
    - Limited role in phagocytosis
    - Have cytoplasmic granules that contain heparin, serotonin, and histamine
    - When stimulated by an antigen, basophils release their granules.

Lymphocytes

- Agranulocytes
  - Lymphocytes
    - Form the basis of cellular and humoral immune responses
    - Two subtypes of lymphocytes are B cells and
      T cells.

Monocytes

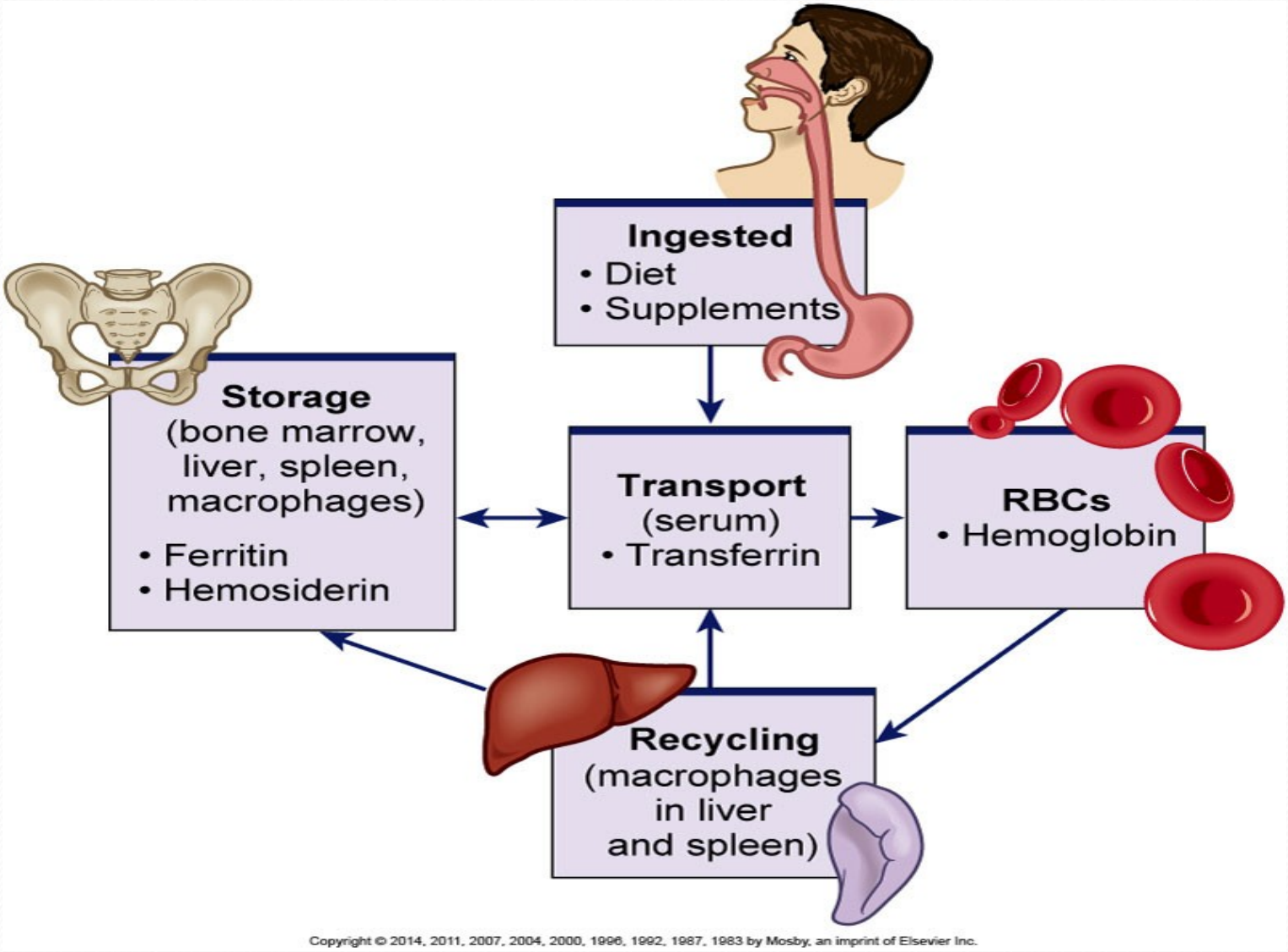
- Agranulocytes
  - Monocytes
    - Potent phagocytic cells
    - Second type of cell to arrive at site of injury
    - When monocytes migrate into tissue, they become macrophages.

Thrombocytes: Platelets

- Platelets (thrombocytes). Arise from megakaryocytes in the red bone marrow
- Initiate the clotting process, plug openings in the capillary wall, and play a role in clot shrinkage and retraction
- Stem cells transform into a megakaryocyte which fragments into platelets.
  - Partially regulated by thrombopoietin

Iron Metabolism

- Obtained from food and dietary supplements
- Absorbed through duodenum and upper jejunum
  - 5-10% of ingested iron is absorbed
    - 1 mg of every 10-20 mg of iron
    - Hemoglobin production is reduced when stored iron is not replaced
    - Transferrin – plasma protein that iron attaches too
- 3% of iron is lost daily in urine, sweat, bile, and epithelial cells in GI tract.



Hemostasis

- The arrest of bleeding
  - Vascular response
  - Platelet plug formation
  - Development of the fibrin clot on the platelet plug by plasma clotting factors
  - Ultimate lysis of the clot

Hemostasis

- Vascular response
  - Immediate local vasoconstrictive response of injured blood vessels
    - Reduces leakage of blood from the injured vessel by reducing vessel size
    - Vasoconstriction gives time for platelet response and plasma clotting factors to be triggered.

Hemostasis

- Platelet plug formation
  - Activated by exposure to interstitial collagen from the injured blood vessel
  - Platelet stickiness is called adhesiveness.
  - Formation of clumps is termed aggregation or agglutination.
  - Platelets facilitate the reactions of the plasma clotting factors.

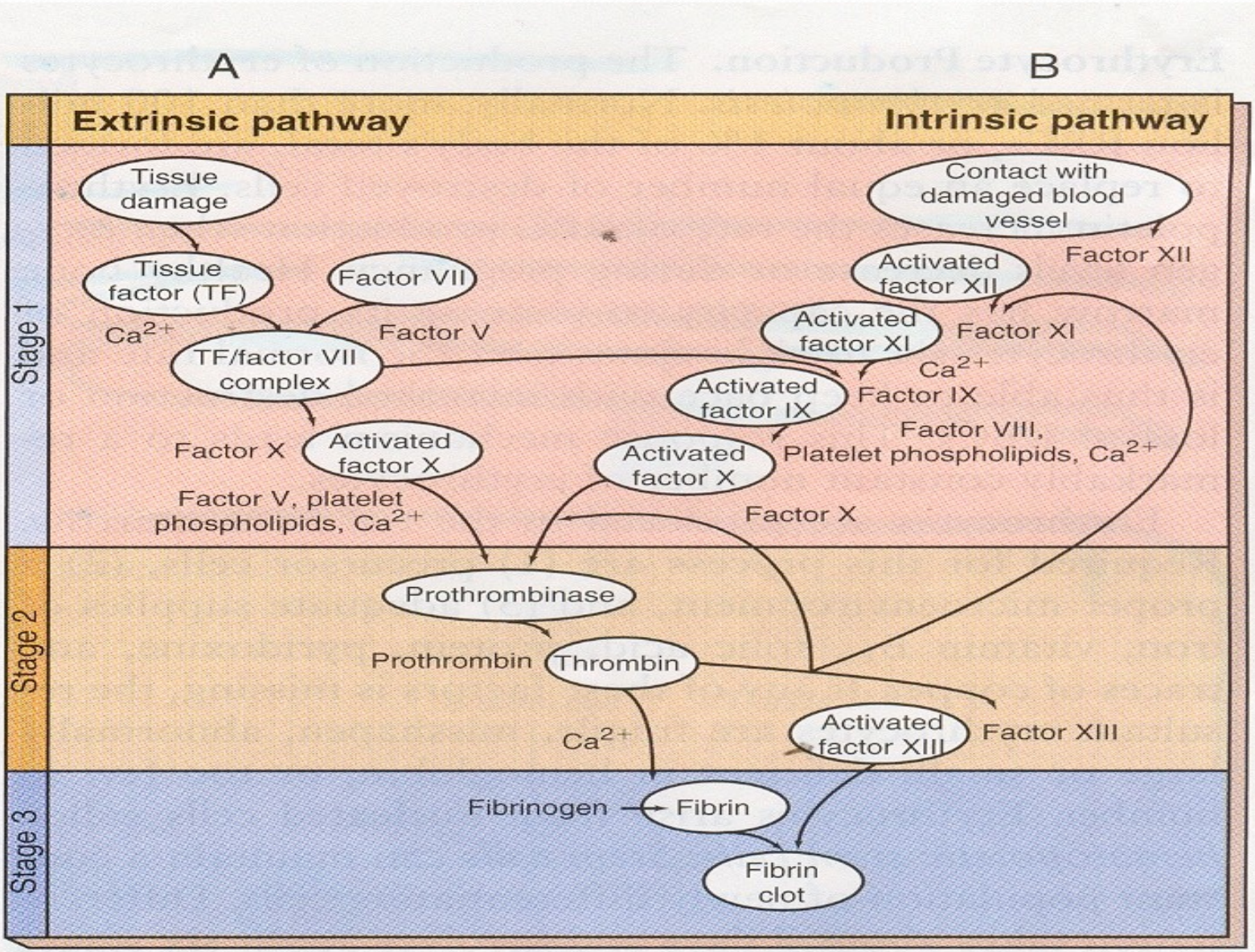
Hemostasis

- Plasma clotting factors
  - Form a visible fibrin clot on the platelet plug
  - Are labeled with both names and Roman numerals
  - Are always present in circulation in inactive forms until stimulated to initiate clotting through one of two pathways

Hemostasis

- Plasma clotting factors
  - Two pathways of clotting
    - Intrinsic pathway is activated by collagen exposure.
    - Extrinsic pathway is initiated when tissue factor or tissue thromboplastin is released from injured tissue.

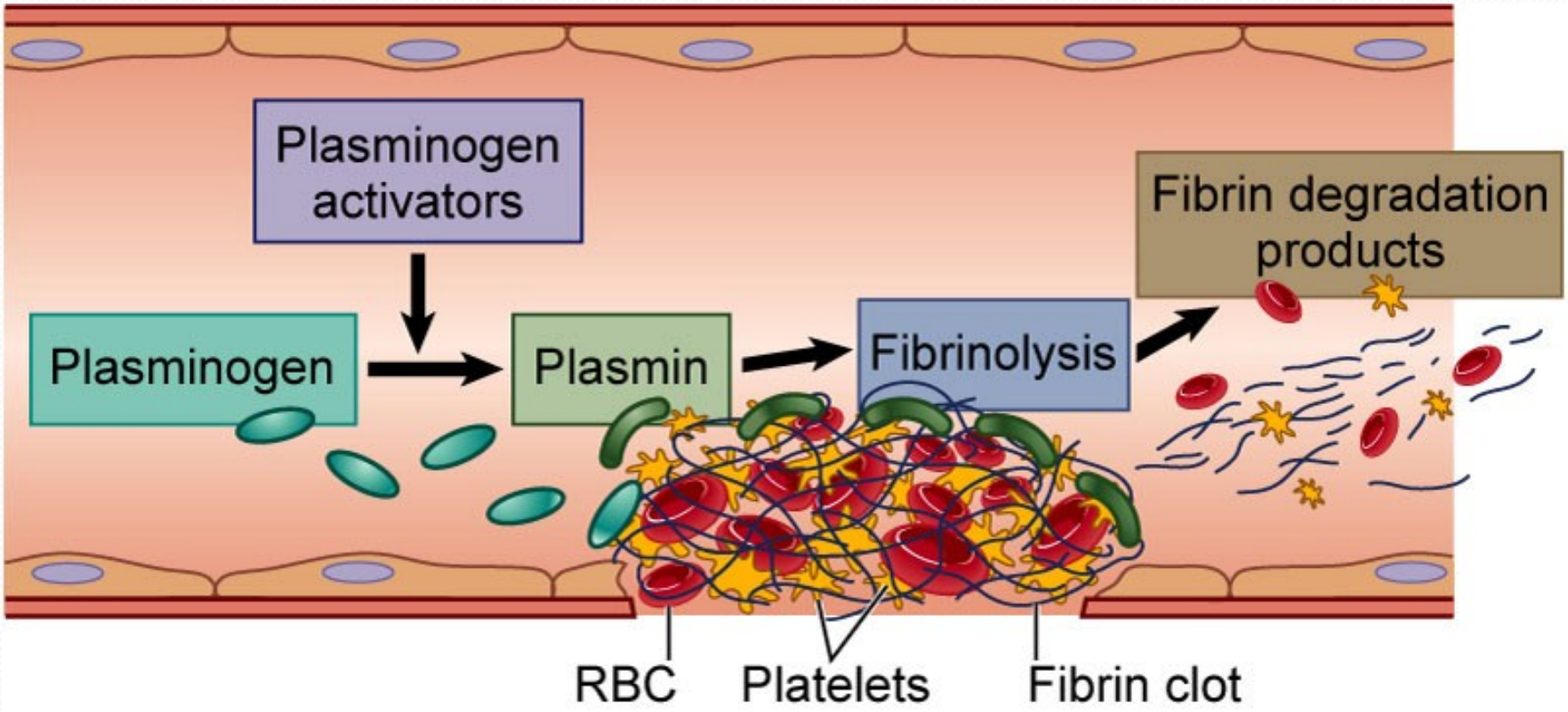
      Thrombin is the most powerful enzyme in the coagulation process because it converts fibrinogen to fibrin, an essential component of a blood clot.


A
B
Extrinsic pathway
Intrinsic pathway
Stage 1
Stage 2
Stage 3
Tissue damage
Tissue factor (TF)
Factor VII
Ca^{2+}
Factor V
TF/factor VII complex
Factor X
Activated factor X
Factor V, platelet phospholipids, Ca^{2+}
Contact with damaged blood vessel
Factor XII
Activated factor XII
Activated factor XI
Factor XI
Ca^{2+}
Activated factor IX
Factor IX
Factor VIII, Platelet phospholipids, Ca^{2+}
Activated factor X
Factor X
Prothrombinase
Prothrombin
Thrombin
Ca^{2+}
Activated factor XIII
Factor XIII
Fibrinogen
Fibrin
Fibrin clot

Hemostasis

- Lysis of clot
  - Anticoagulation, the reverse of clotting, helps keep blood fluid.
  - Anticoagulation occurs by two means.
    - Antithrombins: Interfere with thrombin
    - Fibrinolysis: Process that results in dissolution of the fibrin clot

Fibrinolytic System



Spleen

- Located in the upper left quadrant next to kidney
- Functions can be classified as
  - **Hematopoietic**
    - Able to produce RBCs during fetal development
  - **Filtration**
    - Removes old and damaged RBCs from circulation
    - Removes hemoglobin from RBCs and returns iron component to the bone marrow for reuse
    - Filters out bacteria, especially encapsulated organisms

Spleen

- Functions
  - **Immunologic**: Contains a rich supply of lymphocytes, monocytes, and stored immune globulins
  - **Storage:** Stores RBCs and approximately 30% of total mass of platelets

Lymph System

- Consists of
  - Lymph fluid
  - Lymphatic capillaries
  - Lymphatic ducts
  - Lymph nodes

- Protein and fat from the GI tract and certain hormones are returned to circulatory system.
- Returns excess interstitial fluid to the blood to prevent or reduce edema

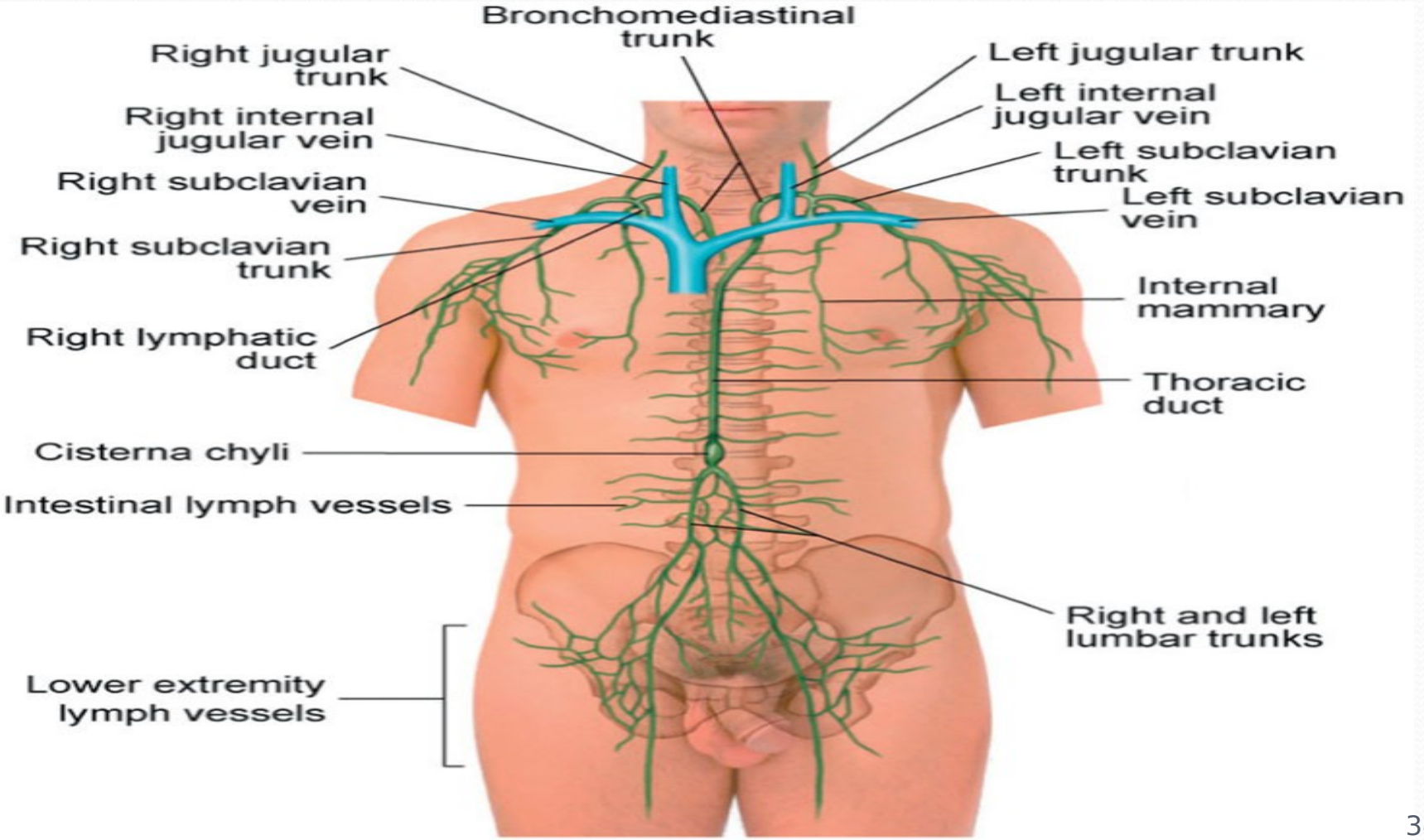
Lymph System

- Lymph fluid
  - Pale yellow interstitial fluid that has diffused through capillary walls
  - Circulates through special vasculature
  - Too much interstitial fluid or reduced absorption leads to lymphedema.
    - May occur as a complication of mastectomy or lumpectomy

Lymph System

- Lymphatic capillaries
  - Thin-walled vessels with irregular diameter
  - Larger than blood capillaries but without valves
  - Unite to form lymphatic vessels that carry all lymph fluid to the right lymphatic duct or the thoracic duct
  - These larger vessels drain into Subclavian veins in the neck.

Lymph Drainage System



From Seidel HM, Ball JW, Dains JE, Flynn JA: *Mosby's guide to physical examination*, ed 7, St. Louis, Mosby, 2011.

Lymph Nodes

- Lymph nodes
  - Small clumps of lymphatic tissue found in groups along lymph vessels at various sites
  - More than 200 lymph nodes throughout the body
  - Largest concentration of lymph nodes is in the abdomen surrounding the GI tract.
  - Primary function is filtration of pathogens and foreign particles carried by lymph fluid.
  - Located both superficially and deep

Liver

- Functions as a filter
- Produces all procoagulants essential to hemostasis and blood coagulation
- Stores excess iron
  - Produces Hepcidin which regulates iron balance

Effects of Aging on the Hematologic System

- Gerontologic considerations
  - Changes in bone marrow, hemoglobin levels, vascular integrity, and blood cell responsiveness and reserves diminish the ability of the older adult to recover from acute illnesses or compensate for chronic diseases.

Assessment of Hematologic System

- Subjective Data
  - Past health history
    - Demographic data
    - Current and past individual and family history
    - Past and current use of medications, herbs, and supplements
    - Surgical history
    - Review of systems using functional health patterns

Assessment of Hematologic System

- Subjective Data
  - Past health history
    - Previous hematologic problems such as anemia, bleeding disorders, or blood diseases
    - Disorders, injuries, or transplants involving the liver, kidney, or spleen
    - Alcohol or IV drug use

Assessment of Hematologic System

- Subjective Data
  - Medications
    - Thorough assessment is important for identifying all substances that can potentially influence hematologic health including
    - Disruption of clotting processes
    - Bone marrow depression
    - Secondary malignancies
    - Bleeding problems

Assessment of Hematologic System

- Subjective Data
  - Surgery or other treatments
    - Splenectomy, tumor removal, prosthetic heart valve placement, excision of the duodenum, partial or total gastrectomy, gastric bypass, and ileal resection are significant.
    - History of bleeding and wound healing
    - Previous blood transfusions

Assessment of Hematologic System

- Subjective Data: Functional Health Patterns
  - Health Perception–Health Management Pattern
    - Usual and present state of health
    - Demographic data
    - Family history and genetically linked disorders
    - High-risk behaviors

Assessment of Hematologic System

- Subjective Data: Functional Health Patterns
  - Nutritional-Metabolic Pattern
    - Weight, dietary pattern, history of cardiac or pulmonary diseases
    - Changes in skin texture or color and presence of petechiae or ecchymotic areas
    - Characteristics of lumps in neck, armpits, or groin

Assessment of Hematologic System

- Subjective Data: Functional Health Patterns
  - Elimination Pattern
    - Bleeding is significant.
  - Activity-Exercise Pattern
    - Weakness or ability to perform ADLs are important.
  - Sleep-Rest Pattern
    - Fatigue not relieved by sleep should be evaluated

Assessment of Hematologic System

- Subjective Data: Functional Health Patterns
  - Cognitive-Perceptual Pattern
    - Arthralgia or aching bones
    - Hemarthrosis
    - Paresthesias, numbness, tingling
    - Changes in vision, hearing, taste, or mental status

Assessment of Hematologic System

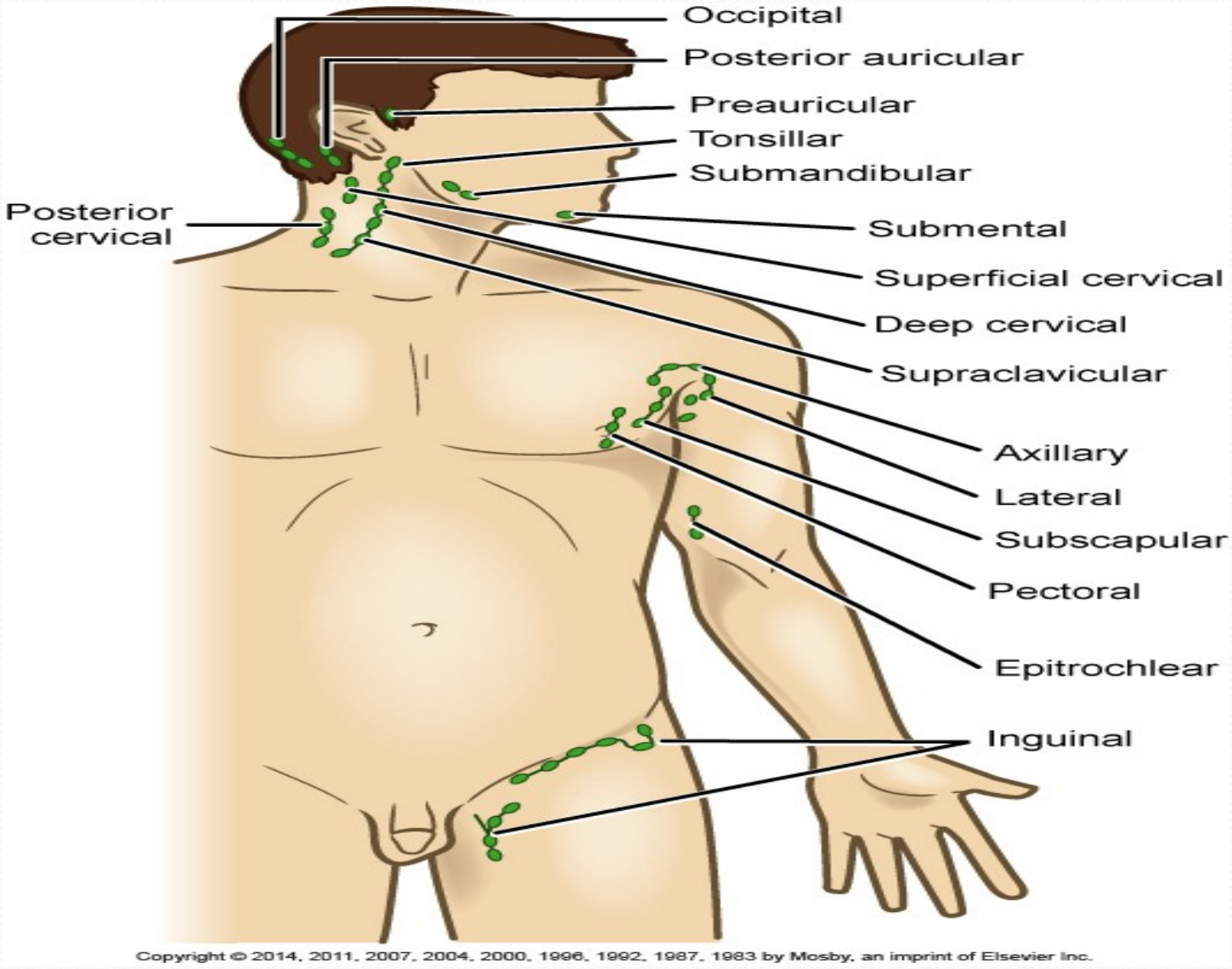
- Subjective Data: Functional Health Patterns
  - Self-Perception–Self-Concept Pattern
    - Impact on function and appearance
  - Role-Relationship Pattern
    - Exposure to radiation or chemicals
    - Military history
    - Impact on usual roles and responsibilities

Assessment of Hematologic System

- Subjective Data: Functional Health Patterns
  - Sexuality-Reproductive Pattern
    - Menstrual history, impotence, or high-risk sexual behaviors
  - Coping–Stress Tolerance Pattern
    - Impact on ability to perform ADLs
  - Value-Belief Pattern
    - Conflicts with transfusions or transplants

Assessment of Hematologic System

- Objective Data
  - Physical Examination
    - Diagnosis of hematologic disorders often requires considering presenting symptoms in context of broader clinical assessment findings and risk factors.
    - Of particular importance are examination of the skin, lymph nodes, spleen, and liver.



Assessment of Hematologic System

- Objective Data
  - Physical Examination
    - Palpation of liver or spleen
    - An enlarged liver is noted by measuring the number of finger-breadths it extends below the rib cage border.
    - Spleen is usually quite difficult to palpate.

Assessment of Hematologic System

- Objective Data
  - Physical Examination
    - Skin assessment
      - Systematic head-to-toe order
      - Petechiae
      - Ecchymoses
      - Spider nevus

Diagnostic Studies of Hematologic System

- Laboratory Studies
  - Complete blood count
    - RBCs, WBCs, and platelets
  - Peripheral smear
    - Morphology of blood cells
  - Pancytopenia
    - Suppression of the entire CBC

Diagnostic Studies of Hematologic System

- Laboratory Studies
  - Red blood cells
    - Total RBC count alone not always diagnostic
    - Hemoglobin value (Hgb)
    - Hematocrit value (Hct)
    - RBC indices
    - Erythrocyte sedimentation rate (ESR/Sed rate)

Hemoglobin (Hgb)

- Main component of the RBC that serves to transport oxygen and carbon dioxide
- Decreased levels of Hgb:
  - Anemia
  - Severe hemorrhage
  - Hemodilution
- Increased levels of Hgb:
  - Hemoconcentration
  - High altitudes
  - Polycythemia

Hematocrit (HCT)

- The percentage of red blood cells in a volume of whole blood
- Normal values: Male: 39-50%, Female: 35-47%
- Decrease and increase same as for Hgb

Red Blood Cell Indices

- RBCI reflects RBC volume, color & hemoglobin saturation

- Consists of:
  - **MCV-** mean corpuscular volume
  - **MCH**- mean corpuscular hemoglobin
  - **MCHC**- mean corpuscular hemoglobin concentration

Diagnostic Studies of Hematologic System

- Laboratory Studies
  - White blood cells
    - Total WBC count
      - Leukopenia
    - Differential count
      - % of each type of leukocyte
      - Neutropenia

Diagnostic Studies of Hematologic System

- Laboratory Studies
  - Platelet count
    - Number of platelets/μL of blood
    - Thrombocytopenia
      - Danger of spontaneous hemorrhage
    - Thrombocytosis
      - Danger of excessive clotting

Diagnostic Studies of Hematologic System

- Laboratory Studies
  - Blood typing and Rh factor
    - Blood group antigens
      - Rh system based on a third antigen, D
      - Rh+ have antigen D.
      - Rh- do not.
      - Coombs test determines Rh status.
      - Significant with transfusions and during childbirth

ABO and Rh Blood Groups

Recipient's Blood Group	A	B	AB (Universal Recipient)	O (Universal Donor)
RBC antigen	A	B	A and B	Neither
Plasma or serum antibody	Anti-B	Anti-A	Neither anti-A nor anti-B	Anti-A and anti-B
Compatible donor for RBC transfusions	A and O	B and O	A, B, AB, and O	O
Compatible donor for plasma transfusions	A and AB	B and AB	AB	A, B, AB, and O
Percent of population	42%	10%	6%	42%

Diagnostic Studies of Hematologic System

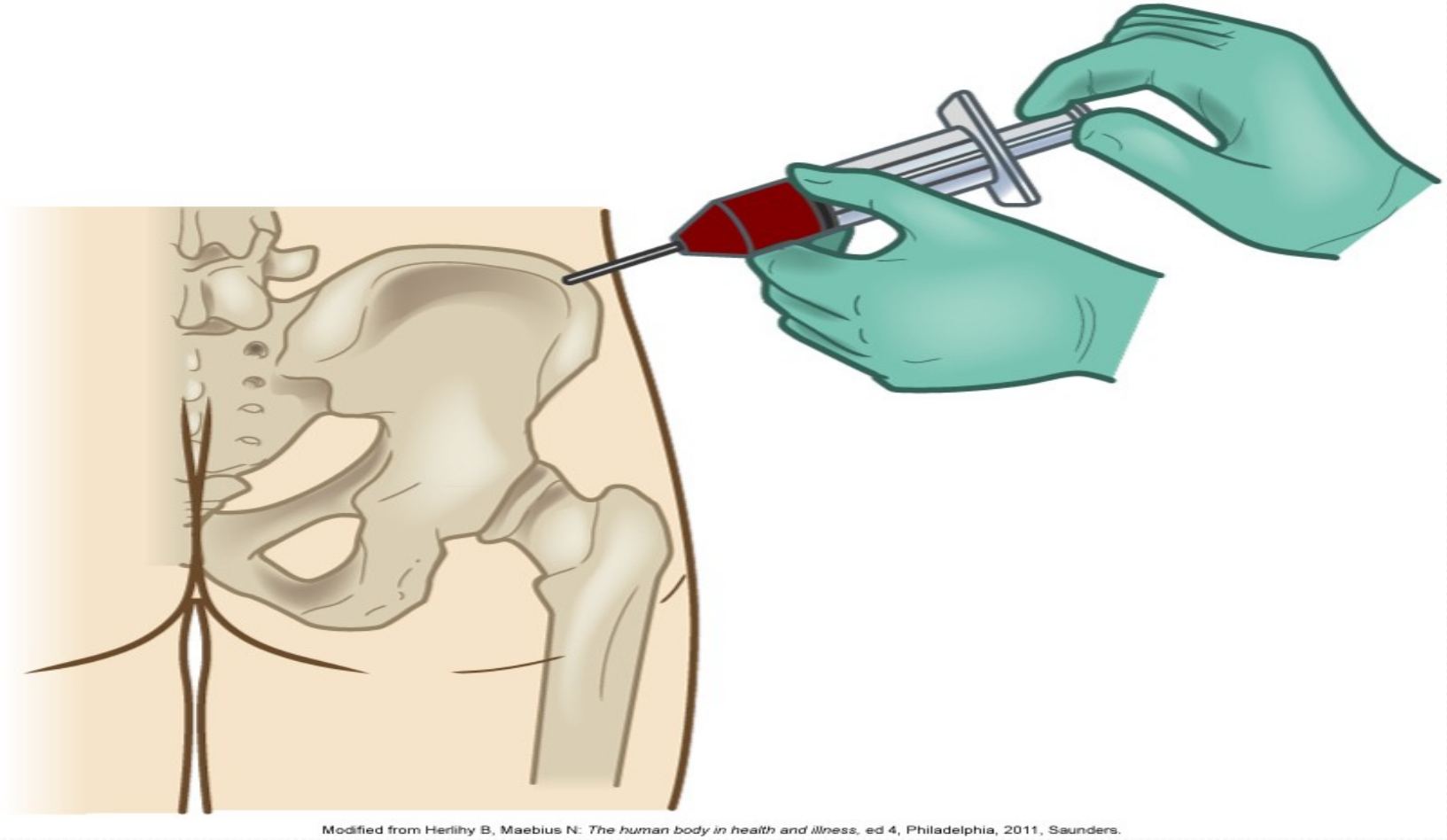
- Laboratory Studies
  - Iron metabolism
    - Serum iron
    - Total iron-binding capacity (TIBC)
    - Serum ferritin
    - Transferrin saturation

Diagnostic Studies of Hematologic System

- Radiologic Studies
  - Computed tomography (CT)
  - Magnetic resonance imaging (MRI)

- Biopsies
  - Bone marrow examination
  - Lymph node biopsy

Bone Marrow Aspiration



Modified from Herlihy B, Maebius N: *The human body in health and illness,* ed 4, Philadelphia, 2011, Saunders.

Diagnostic Studies of Hematologic System

- Biopsies
  - Lymph node biopsy
- Molecular cytogenetics and gene analysis
  - From bone marrow and lymph node biopsy samples
    - Fluorescent in situ hybridization (FISH)
    - Spectral karyotyping (SKY)